ET Docket 10-23 & 10-27

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JUN 24 2011

Federal Communications Commission
Office of the Secretary

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June 24, 2011

BY HAND DELIVERY
Marlene H. Dortch, Esq.
Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Dear Ms. Dortch:

Attached is a submission from Sutron Corporation. Kindly associate this document with the "Request for Waiver" filed by Sutron on January 3, 2011. That request has not appeared on public notice and does not have a docket number.

Please contact me with any questions.

Respectfully submitted,

Mitchell Lazarus

Mitchell Lazarus
Counsel for Sutron Corporation

cc: Karen Ansari, Rashmi Doshi, Bill Hurst, Steve Jones, Julius Knapp, Geraldine Matise, Tom Phillips, Bruce Romano, Mark Settle, Anh Wride

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Overview

Sutron is developing a downward pointing radar designed to accurately measure the water levels of rivers, lakes and streams. The technology used is wideband time of flight radar: the measurement of time that the radar pulse takes to travel to the water level and return to the emitting device.

Sutron originally designed this radar to operate within the 15.250 band (FCC ID HDBRLR-0003-1) as that category most closely matches the parameters of the device. However, the bandwidth permitted under that category is proving too narrow for the highly accurate performance demanded by some customers. With wider bandwidth operation, the radar devices can achieve their desired operating accuracy.

Sutron accordingly filed a waiver request on January 3, 2011, seeking to use the frequency range 5460-7250 MHz.

This submission follows a meeting with FCC staff on June 2, 2011. It demonstrates both empirically and theoretically why the additional bandwidth will yield the desired result of higher measurement accuracy, while the proposed alternative of higher power does not achieve that result.

Summary of the following report:

- Average horizontal emissions are too low for Sutron's lab to measure, and in any event are below –72.8 dBm EIRP (which in turn is 2 dB below the level estimated in the waiver request).
- Direct measurements establish a strong inverse relationship between pulse width, on the one hand, and occupied bandwidth, on the other. (A narrow pulse width, needed for measurement accuracy, thus imposes requirements for bandwidth.)
- Theoretical treatment likewise supports the inverse relationship between pulse width and occupied bandwidth.
- Measurements show that increasing power has no effect on accuracy.

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Supplemental Information for the FCC with regard to the Sutron Corp Waiver.

Discussions at the June 2 revolved around how the emission bandwidth impacts the accuracy of water level measured. FCC staff asked Sutron for the following:

1. Provide measured data (as opposed to estimated data) for the horizontal emissions resulting from mounting the main boresight vertically downwards.
2. Describe test data showing impact of occupied bandwidth on time domain pulse width.
3. Provide the basic theory linking bandwidth to system accuracy.
4. Provide test data showing results, in terms of measurement accuracy, of increasing RF transmission power above the FCC limits while remaining in the original 15.250 band.

1) Request for Measured Data on the Horizontal axis.

Sutron originally estimated an average horizontal emission from the downward pointing radar to be approximately 28.9 dB down from boresight levels, based on antenna patterns. A test radar unit configured for operation (with the RF bandwidth matching the waiver 5460 to 7250 MHz) was sent to Intertek so as to obtain readings from an accredited laboratory. Figure 1 shows the average level of the main lobe of the radar as measured in the boresight at 1 meter, also identified by the display line referenced at 52.7 dBuV. The other two lines on the plot below represent the noise floor of the spectrum analyzer and the sweep of the signal at the horizontal axis in which they are virtually identical. (In figure 1 it is difficult to see the difference in the noise floor and the horizontal sweep as the traces reside on top of each other.) This implies that the horizontal emissions are below the noise level of the spectrum analyzer. This yields a difference of 52.7 – 23.5 = 29.2dB. The test sample also yielded an average boresight value of -43.6 dBm EIRP. Note Intertek did have to procure an additional LNA in order to help reduce the noise floor in order to make these tests and this was the lowest level for the noise floor that they could achieve at 6 GHz.

The average horizontal emissions are at or lower than -72.8 dBm EIRP.

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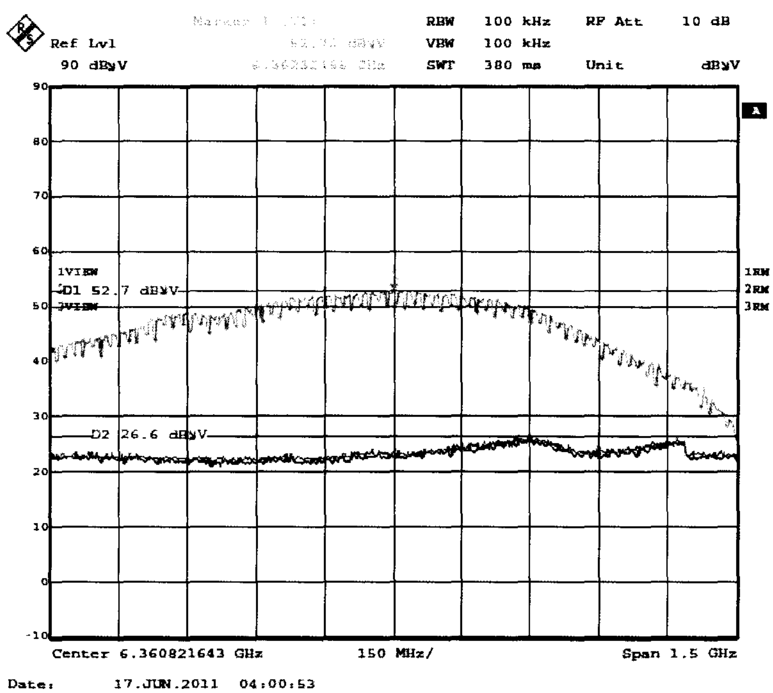
The graph below shows a plot of the Emissions Noise floor (green trace) of the 10 meter chamber. The test sample was measured at 0 degrees (yellow trace) and 90 degrees (blue trace).

Results: The reading attempted at 90 degrees is at or below the noise floor measurement.



Richard Bianco
EMC Engineering Team Leader

Figure 1

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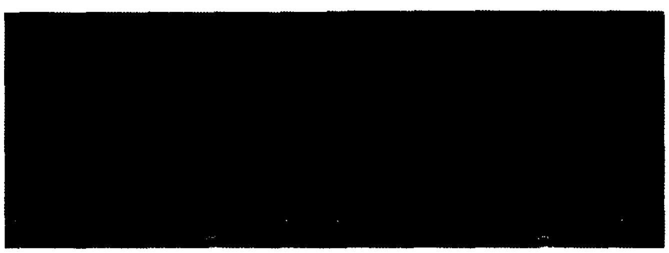
2) RF Bandwidth relationship to the Time domain pulse

The experimental data plots below show the relationship of the time domain (see blue trace) and the RF transmission bandwidth stated below each plot. Included in the plot is the magenta colored trace which reflects the envelope of the RF signal, and the green trace which reflects the derivative of the envelope waveform, which is key to the accuracy of the radar. For example, the first plot has a wide bandwidth of 2.4 GHz and a corresponding time domain pulse (blue) that is relatively short. The last pulse with a much lower 640 MHz bandwidth signal has the corresponding longest time domain pulse.

These plots confirm that a very narrow pulse will generate wider RF bandwidth. The green trace shows how the lower bandwidth results in a much more undefined pulse that makes it difficult to identify the point in time that reflects the actual water level. In short, wider bandwidth provides greater accuracy.

2400 MHz 1600 MHz



1200 MHz 800 MHz

800 MHz (again) 640 MHz

Figure 2

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Figure 3 is a plot showing the performance where the signal bandwidth was configured to meet the waiver request values of 5.46 to 7.25 GHz (BW=1.79 GHz). This shows performance meeting specifications, achieved with the wider RF bandwidth waveform.

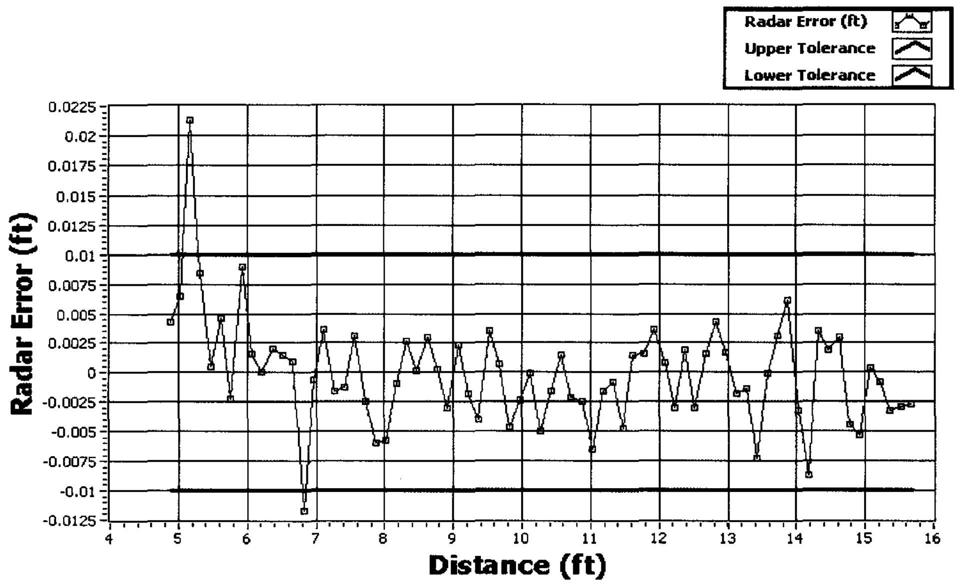

Figure 3

3) Theory behind relationship of RF Transmission Bandwidth and Pulse Width

The radar pulse employs an RF carrier signal enclosed in an envelope signal. The received envelope signal is processed to estimate the distance to the water surface from the radar sensor.

Theoretically, the received envelope in the radar sensor may be characterized as a Gaussian pulse, as defined in the equation below:

$$f(t) = e^{-\alpha t^2} \tag{1.1}$$

where t is a continuous time parameter and α is a scaling factor.

The time-domain representation of Gaussian pulse for a narrow and wide pulse width case can be seen in 4 below:

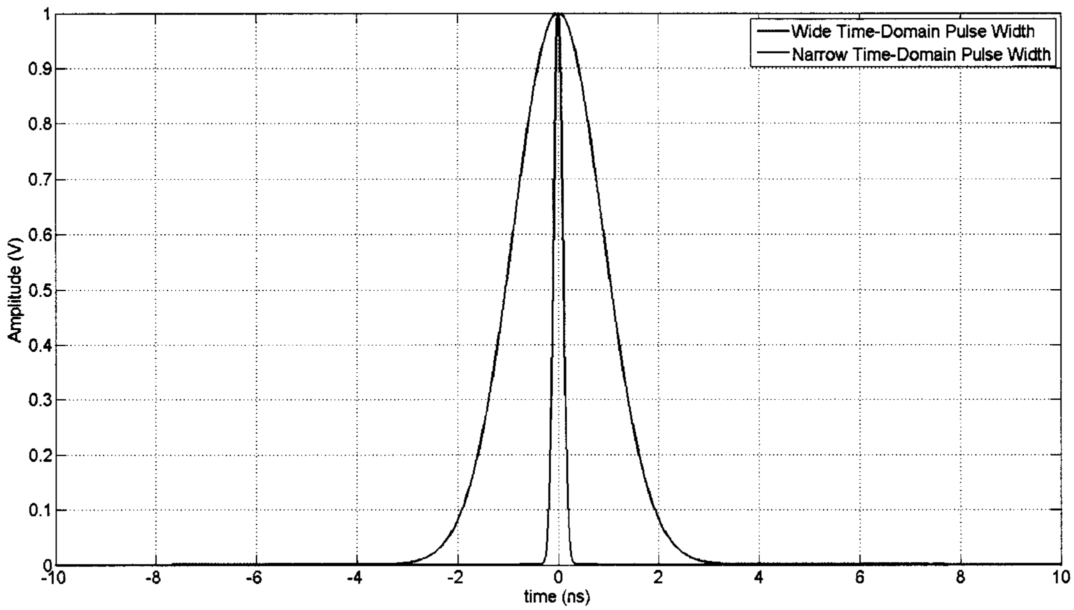

Figure 4: Time Domain Representation of a Gaussian pulse with Narrow and wide time-domain pulse widths

The Fourier Transform of the Gaussian pulse can be computed as:

$$F(f) = \int_{-\infty}^{\infty} f(t) e^{-j2\pi ft} dt \tag{1.2}$$

Simplifying equation (1.2), the frequency domain representation of time-Domain Gaussian pulse defined in equation (1.1), can be obtained as:

$$F(f) = \sqrt{\frac{\pi}{\alpha}} e^{-\frac{\pi^2 f^2}{\alpha}} \tag{1.3}$$

The frequency-domain representation of Gaussian pulse for a narrow and wide pulse widths can be seen in figure 5 below:

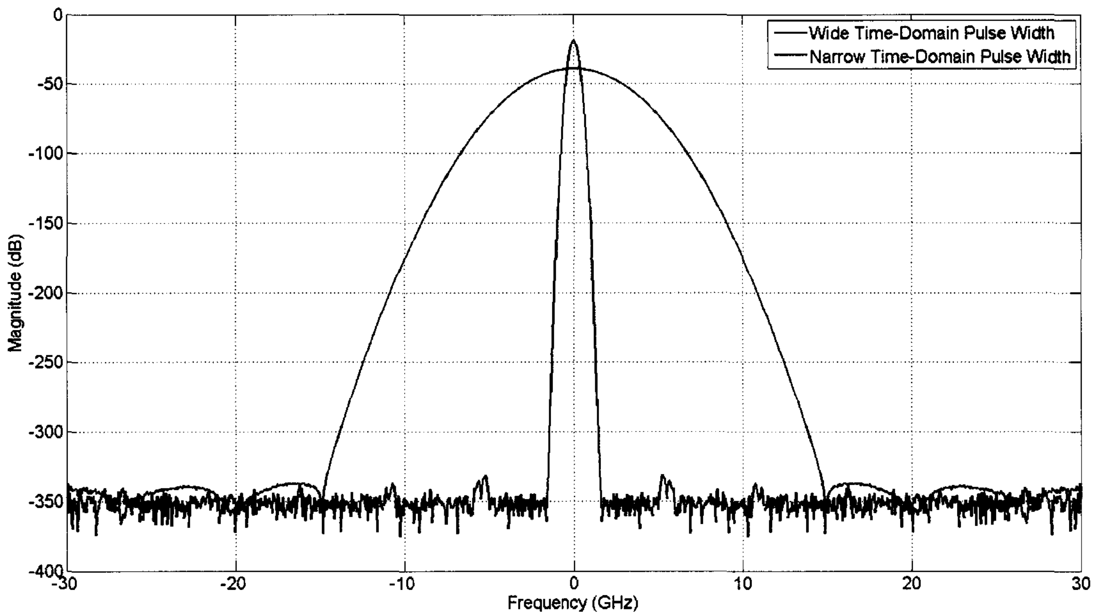

Figure 5: Frequency Domain Representation of a Gaussian pulse with Narrow and wide time-domain pulse widths

The following may be observed from the above plots:

- The narrower pulse in the time domain transforms into a wider bandwidth pulse in frequency domain, and conversely,
- A wide pulse in time domain transforms into a narrow bandwidth pulse in frequency domain.

This is the fundamental reason the sharper (more narrow) time domain signal needed for more accurate radar performance comes at the expense of wider RF (frequency domain) bandwidth. Stated another way, the slow risetime associated with the narrow bandwidth signal makes it difficult for the device to accurately locate the water level, due to the difficulty that the radar has in taking a precise value off a slowly rising edge.

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4) Increasing RF power and its impact to the Desired Accuracy of the Radar.

Commission staff asked whether Sutron could raise the power of the signal, instead of widening the bandwidth, to achieve the desired accuracy. Sutron modified the power output of a 15.250 compliant radar unit and recorded the performance in several steps shown below.

First, the transmit horn was removed and the output of the radar was directly connected to a spectrum analyzer. This permits reproducible lab tests by making measurements relative to a previously certified radar board under 15.250, also referred to below as 'reference'. The power was increased to approximately 12 dB over the reference, where the reference was 5.9 dB below the max permitted value.

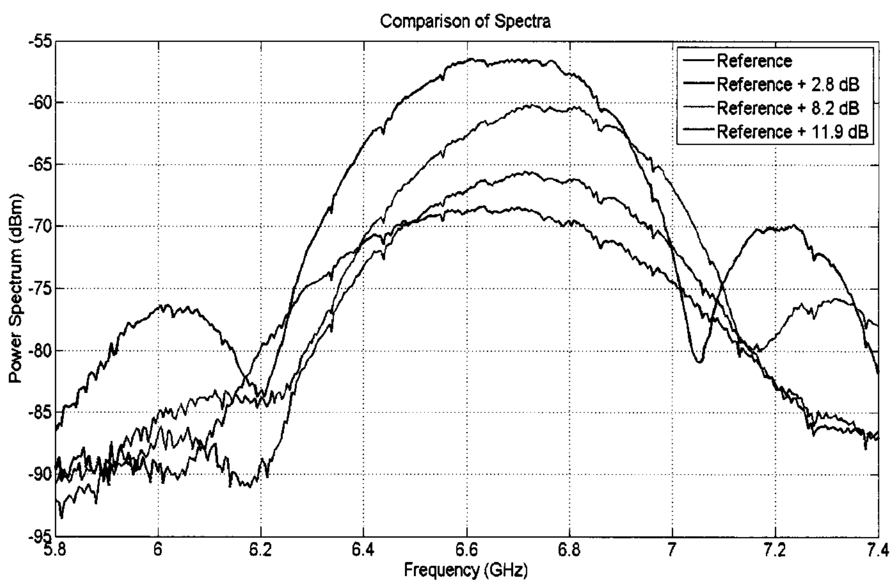

Figure 6

Each power level generated above permitted the performance of the radar to be captured and quantified. Figure 6 shows the emissions plotted against frequency for each power level. Figure 7 shows the measurement error in feet over a 15 foot range, for each power level. The desired operation should fall between the green and red horizontal lines. Note that none of the increases in power yielded an improvement in accuracy.

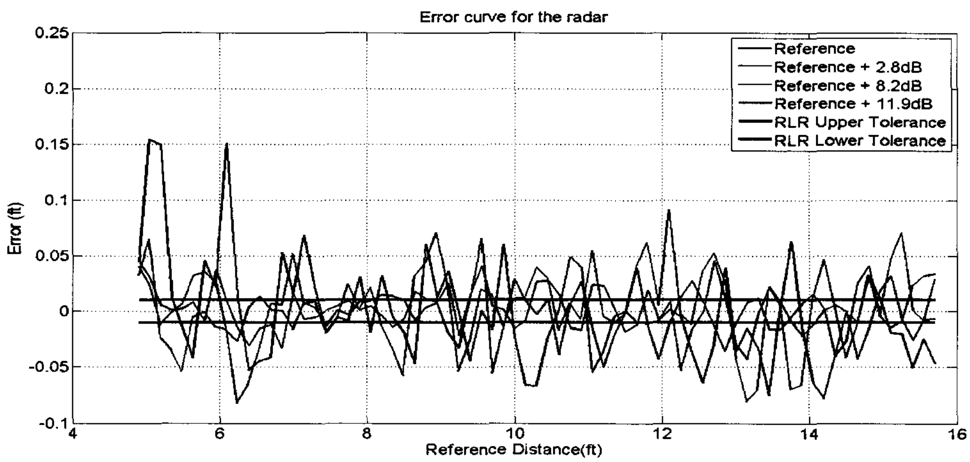

Figure 7

Compare this plot to Figure 3, above, which shows that increasing the occupied bandwidth to the value specified in the waiver request brings the error down to an acceptable range.

Figure 8 is another way of displaying the above results but the error is calculated to be an RMS error. The key observation is that the performance did not improve with the increase in power and actually increased slightly most likely due to measurement anomalies.

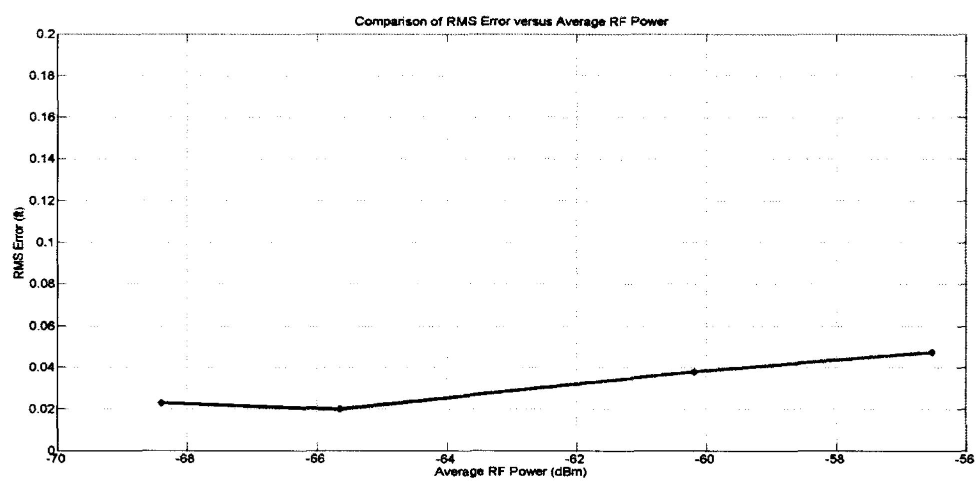

Figure 8

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Summary

The key points regarding this response are the following:

1) The FCC's request for measured data vs estimated data for average horizontal emissions are presented. While the test lab was unable to achieve a lower noise floor at 6 GHz, and acknowledging that there should be a minimum of 6 dB between the measured signal and the noise floor, one may still see at least 29.2 dB down to the noise floor with no signs of signal present. If hypothetically there was a signal at the level of the noise floor, one could infer that the signal would be 3 dB lower than the displayed trace as the summation of the two signals would raise the result by 3 dB. The average horizontal emissions are at or lower than -72.8 dBm EIRP.
2) Sutron has supplied empirical data indicating the relationship of the bandwidth to the time domain pulse width and has established that the performance is improved by wider channel bandwidth.
3) Sutron has provided a brief summary of the theory behind RF channel bandwidth and accuracy.
4) Sutron ran tests with a radar device configured with the bandwidth defined in 15.250 (5.925 to 7.25 GHz) and increased power, and found no improvement in accuracy over the 12 dB power increase range.

The above report should help to clarify why Sutron feels that providing the additional bandwidth for operation is more critical to the performance of the downward pointing radar device.

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24th June 2011